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BURNERS FOR DISPOSAL OF ROCKET PROPELLANTS

AIR FORCE ROCKET PROPULSION LABORATORY

JUNE 1976

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BURNERS FOR DISPOSAL OF ROCKET PROPELLANTS

FINAL REPORT

AIR FORCE ROCKET PROPULSION LABORATORY
EDWARDS AFB, CALIFORNIA 93523

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JUNE 1976

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FOREWORD

This report describes the design, development, and operation of burners which will be used at the Air Force Rocket Propulsion Laboratory to dispose of propellants that are surplus from rocket research efforts. The burners will become components of the Toxic Waste Disposal Facility, a propellant disposal system that includes scrubbers, computer-controlled flow loops, remotely controlled manipulators, and evaporation-settlement ponds. These development efforts were performed during September 1972 through July 1975 on projects 5599TWYZ and 683MTWYZ. The test project engineer responsible for the design and operation of the Toxic Waste Burner was Mr. John Denker (AFRPL/TEBB) of the Test and Support Division, who is the author of this report.

This report has been reviewed by the Information Office/DOZ and is releaseable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations. This report is unclassified and suitable for general public release.

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Burners were designed, fabricated and used to dispose of toxic rocket propellants and other materials that are residuals from propulsion research programs conducted by the Air Force Rocket Propulsion Laboratory (AFRPL). Burners were developed to burn liquid oxidizers, liquid fuels, and solid propellants.

Burners for the liquid wastes were designed and fabricated by AFRPL utilizing commercially available components including sheet steel, --

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industrial blowers and perforated nickel alloy sheeting. The burner developed for burning solid propellants is a modified ammunition deactivation furnace which was purchased from the Army's ammunition depot at Tooele, Utah.

The burner developed for disposal of liquid propellant oxidizers burned in excess of 600 pounds/hour of nitrogen tetroxide by reacting it with propane which produced exhaust gases in the range of 1000°F that contained less than 1000 parts/million of nitrogen oxides. The fuel burner disposed of over 1000 pounds/hour of liquid propellant including hydrazine by burning it in air to produce exhaust gases in the 1300°F range which contained low levels of nitrogen oxides. An Army ammunition deactivation furnace was modified to dispose of solid propellants. Four hundred pounds/hour of solid Minuteman propellant were burned which produced exhaust gases having 160 parts/million of nitrogen oxides from Class 2 propellants and 1200 parts/million from Class 7 propellants. The population of solid particles of aluminum oxides produced were predominantly of sub-micron sizes.

These burners are suitable for operational use in detoxification of rocket propellant research residues. They will be installed in the Toxic Waste Disposal Facility located at the Air Force Rocket Propulsion Laboratory, Edwards AFB, California and used to dispose of the toxic residue from its research programs.

PREFACE

The author hereby expresses his appreciation to the many people who have contributed to the success of this program. These include people at Tooele Army Depot, Tooele, Utah (TAD), who participated in developmental evaluation of the ammunition deactivation furnace which was purchased from Tooele for burning solid propellants. Mr. Frank Crist cooperated in planning and scheduling AFRPL-TAD work. Mr. Dan Hill provided valuable sampling-analysis of exhaust products, and Mr. Francis Cook directed their operational people.

Radford Army Ammunition Depot (Mr. Truman Daniels) provided advice and demonstrated its explosives disposal system which aided in the search by AFRPL for suitable equipment and gave valuable knowledge of catalytic conversion of nitrogen oxides to harmless gases.

Picatinny Arsenal (Mr. Milton Roth) described its fluidized bed approach to solid explosives disposal and provided data on grinding and pumping explosives.

AFRPL personnel provided technical guidance and design support, fabricated burners, and sampled-analyzed the exhaust products. Mr. Curtis Selph predicted combustion products from liquid propellants, and Lt S. Andes described probable optimum combustion staging for disposal of the N_2O_4 and IRFNA. Mr. John Nakamura and Mr. Leon Triplett performed sampling and analysis of exhaust products.

Test area personnel performed the developmental burner tests including data recording, propellant handling, and installation and operation of the burners.

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NOMENCLATURE

Actual Cubic Feet per Minute	ACFM
Chlorine Trifluoride	CTF
Diethyltriamine	DETA
Feet per Second	FPS
Government Furnished Equipment	GFE
Hydrazine	N_2H_4
Inhibited Red Fuming Nitric Acid	IRFNA
Instrumentation Specification Sheet	ISS
Mixed Hydrazine Fuel	MHF
Nitrogen Tetroxide	N_2O_4
Pentaborane	B_5H_9
Propane	C_3H_8
Rocket Propellant 1	RP1
Toxic Waste Disposal Facility	TWDF
Unsymmetrical Dimethylhydrazine	UDMH

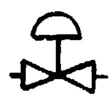
SYMBOLS


PNEUMATIC OPERATED SPRING CLOSING

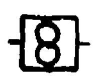

PRESSURE RELIEF


PRESSURE REGULATOR


MANUAL


DIAPHRAGM OPERATED


SOLENOID OPERATED


FLOW METER


CHECK VALVE


PRESSURE TRANSDUCER


THERMOCOUPLE

INTRODUCTION

Burners capable of combusting rocket propellant wastes are a major subsystem of the AFRPL Toxic Waste Disposal Facility (TWDF). This facility is designed to burn liquid or solid propellants, treat the combustion products by scrubbing and cyclone separation, collect in evaporation-settling ponds the solids produced, and eject the scrubbed gases vertically to the atmosphere. The Air Force Rocket Propulsion Laboratory agreed to furnish burners as Government Furnished Equipment (GFE) to the contractor for TWDF chosen by the Army Corps of Engineers and in 1972 contacted commercial and government sources in attempts to locate suitable burners. A kiln type burner developed by the Tooele Ammunition Depot (TAD) was chosen for burning solid propellant wastes because it is a proven, sturdy, reliable unit which meets the requirements of the AFRPL. It may be successfully fed a broad spectrum of sizes, shapes, and composition of propellant wastes including test tube, liter bottle, and half-gallon carton sizes of solid materials as well as propellant chips, powder, cartridges, and tensile test specimens. The commercially available burners which were discovered did not meet the requirement for burning liquid propellants, thus making it necessary to develop them at the AFRPL. The design requirements, photographs, operating instruction, and test history for these liquid propellant burners are included in this report.

BURNER DEVELOPMENT FACILITY

Test Area 1-46 of the AFRPL was chosen as the site in which to develop the burners for the TWDF because it had an available test position containing the necessary equipment and facilities required for the program. A list of the appropriate facility systems available for the testing follows:

a. Propellant tanks:
   Chlorine trifluoride (CTF), 500 gallons, 2000 psi
   Nitrogen tetroxide (N_2O_4), 500 gallons, 2000 psi
   Hydrazine (N_2H_4), 250 gallons, 2000 psi
   Unsymmetrical dimethyl hydrazine (UDMH), 250 gallons, 2000 psi
   Furnace fuel, 500 gallons, 600 psi

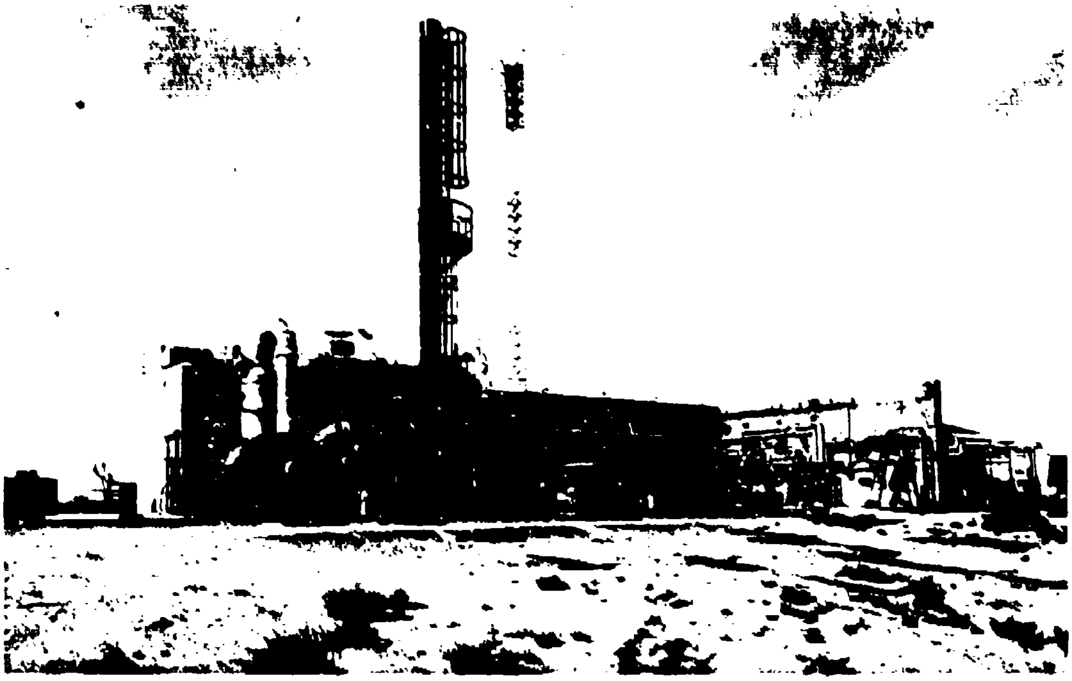


Figure 1. The Toxic Waste Disposal Facility

b. Gas systems:

Nitrogen

5000 psi

Lower regulated pressures

c. Water systems

d. Instrumentation systems:

Direct inking charts (30)

Digital format tape recorder (60 channels)

Digital meters (12)

e. Control systems:

Valve controls

Motor controls

Sampler controls

f. Television:

Color, for exhaust stream color and opacity

Monochrome, for equipment status during burns

These systems were operated from the control center by technicians at the direction of the test engineer. A typical burner operation followed this sequence:

a. The burner was assembled, and propellants were loaded according to instructions written in an engineering request (ER).

b. The instrumentation systems were prepared according to the instrumentation specification sheet (ISS).

c. The test area was cleared, and people were assembled in the control center according to the approved countdown which was followed throughout the operation.

d. The burner and instrumentation were started; data points were generated by varying flowrates of the propellant, propane, and as directed by the test engineer.

e. The samplers-analyzers were operated by the res. le chemical laboratory people at times of interesting burn conditions.

f. Following the burner operations, data tapes were processed to obtain values of parameters such as flowrate, temperature, and emission levels.

Figure 2 shows the control console, the flowrate controllers, and the recorders in the control center. The propellant tanks, the propellant lines, and the burner installations in the test stands are shown in Figure 3; these are four hundred feet from the control center.

Operation of the solid burner was similar; instrumentation and mechanical test preparations were made, and a supply of waste propellant was obtained from another area. However, when the test area was cleared, three technicians remained at the burner to load the propellants onto the feed conveyor and provided a mutual safety support.

TEST EQUIPMENT

Measurements were made during the development and operation of the toxic waste burners of temperature, pressure, flowrate, and pollutant levels. The following equipment was used to make the required measurements:

Flowrate measurement

Turbine type flowmeter:

N_2O_4	- Potter, model 10C1512A, .4 to 2.75 GPM
Coolant H_2O	- Potter, model 1/2 5377, 1 to 10 GPM
N_2H_4	- Flow Technology, model FT 8 M 4 L 8, .6 to 4 GPM
Air (velocity)	- Flow Technology, FTP 48 GJS, 100 to 10,000 FPM
C_3H_8	- Flow Technology, FT 8 M 20 GB, 1 to 10 ACFM

Pressure measurement

Strain gage type transducer:

N_2O_4 supply	- Taber model 217SA, 0 to 200 psig
N_2H_4 supply	- Taber model 217SA, 0 to 200 psig
Propane supply	- Taber model 217SA, 0 to 200 psig

Temperature

Resistance type transducer:

N_2H_4	- Rosemount, model 176P, -435 to +500°F
50/50	- Rosemount, model 176P, -435 to +500°F
N_2O_4	- Rosemount, model 176P, -310 to +250°F

Thermocouple type:

Combustor	- Chromel-alumel, -310 to 2500°F
C_3H_8	- Chromel-alumel, -310 to 2500°F

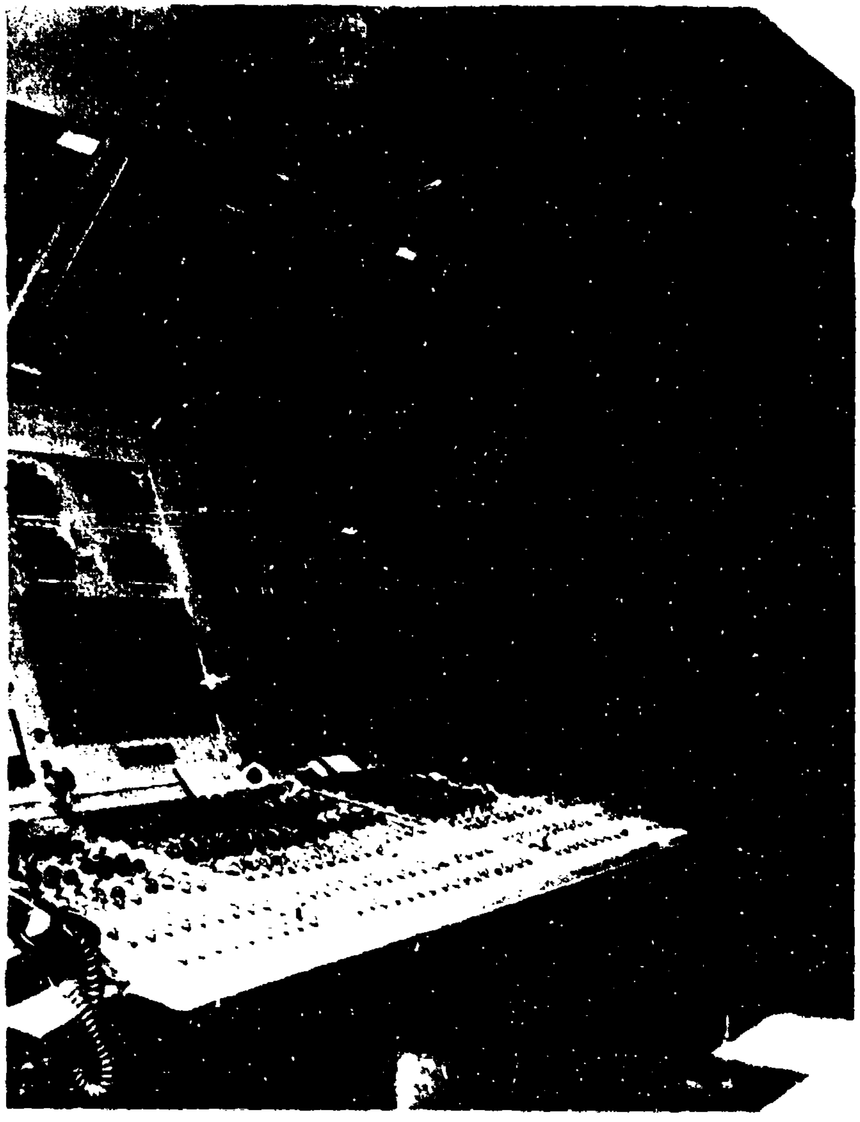


Figure 2. Control Console and Instrumentation Equipment in the 1-46 Control Center

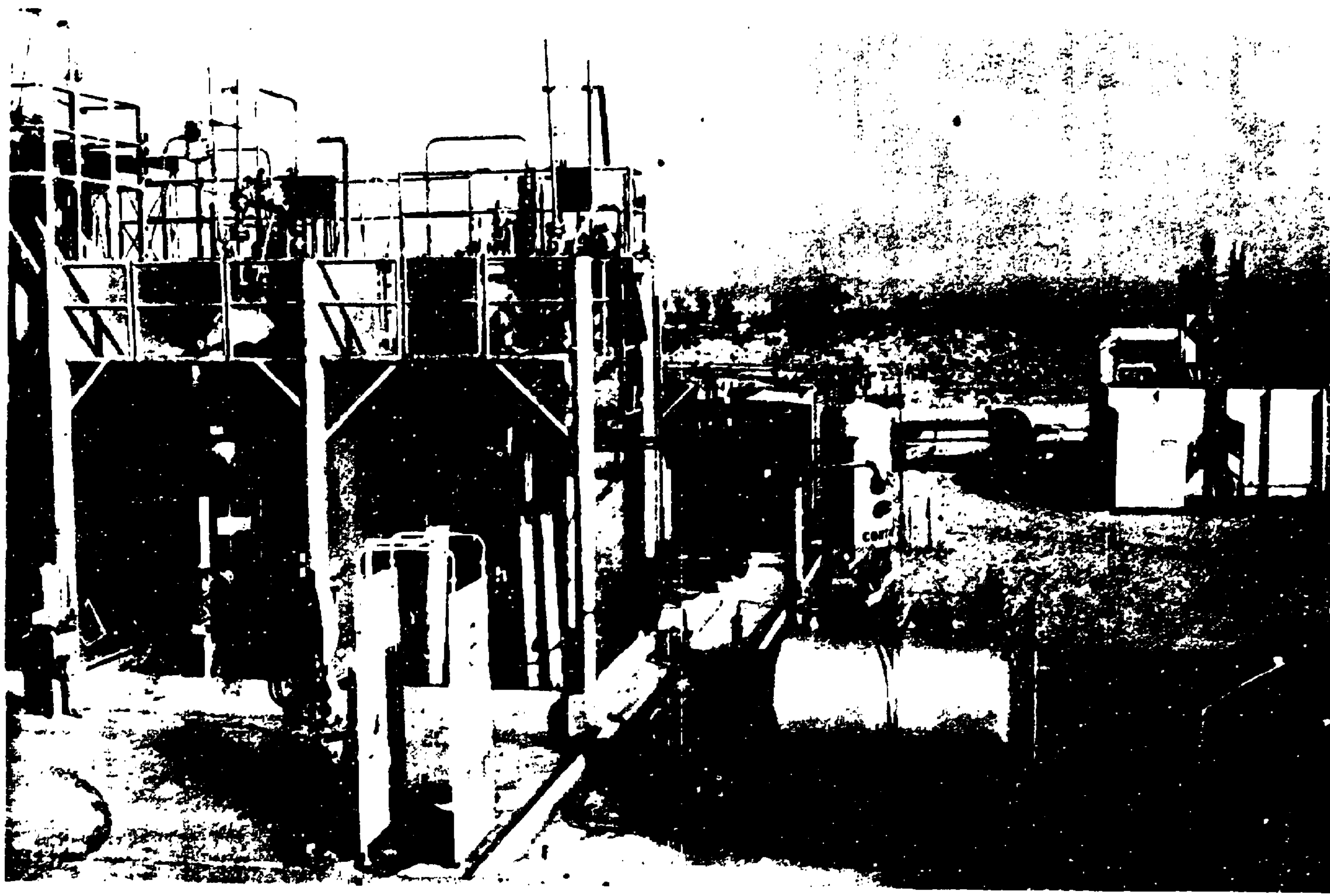


Figure 3. The Toxic Waste Burner Development Facility

Pollutant level

Nitrogen oxides	-	Beckman Instrument Inc., model 315B
Nitrogen oxide	-	Beckman Instrument Inc., model 951
Exhaust color and opacity	-	Cohu, color, video system, model 1220B

POLLUTION EMISSION GOALS

The AFRPL must comply with Kern County Air Pollution Control District regulations. The Federal Clean Air Act directs the states to formulate plans which control pollution. Pursuant to this directive, Kern County published regulations which are designed to comply with the state and federal requirements.

The emission restraints for stationary sources were applied to the Toxic Waste Disposal Facility. The regulations are not applicable to performance of the burner alone but apply to the combined performance of the burners, scrubbers, and quench tower that are the total disposal system. The scrubbers, venturi separator, and quench tower will remove particulates, the halogen compounds including hydrogen chloride, and much of the condensible materials. The burners must not exceed the pollution limitations, if any, for materials such as nitrogen oxides, sulphur compounds, carbon monoxide, and carbon dioxide which will pass through the scrubber systems to atmosphere.

The following are applicable excerpts from Kern County's regulations:

Rule 401 Visible Emissions A person shall not discharge into the atmosphere, from any single source of emission whatsoever, any air contaminant for a period or periods aggregating more than 3 minutes in any one hour which is:

a. As dark or darker in shade as that designated as No. 1 on the Ringelmann Chart, as published by the United States Bureau of Mines.
b. Of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in subsection (a) of this Rule.

Rules 401(a) and 401(b) shall not apply if it is shown by the owner or operator of the emission source that the emission source was, at the time of violation of Rules 401(a) and 401(b), in compliance with other applicable emission standards.

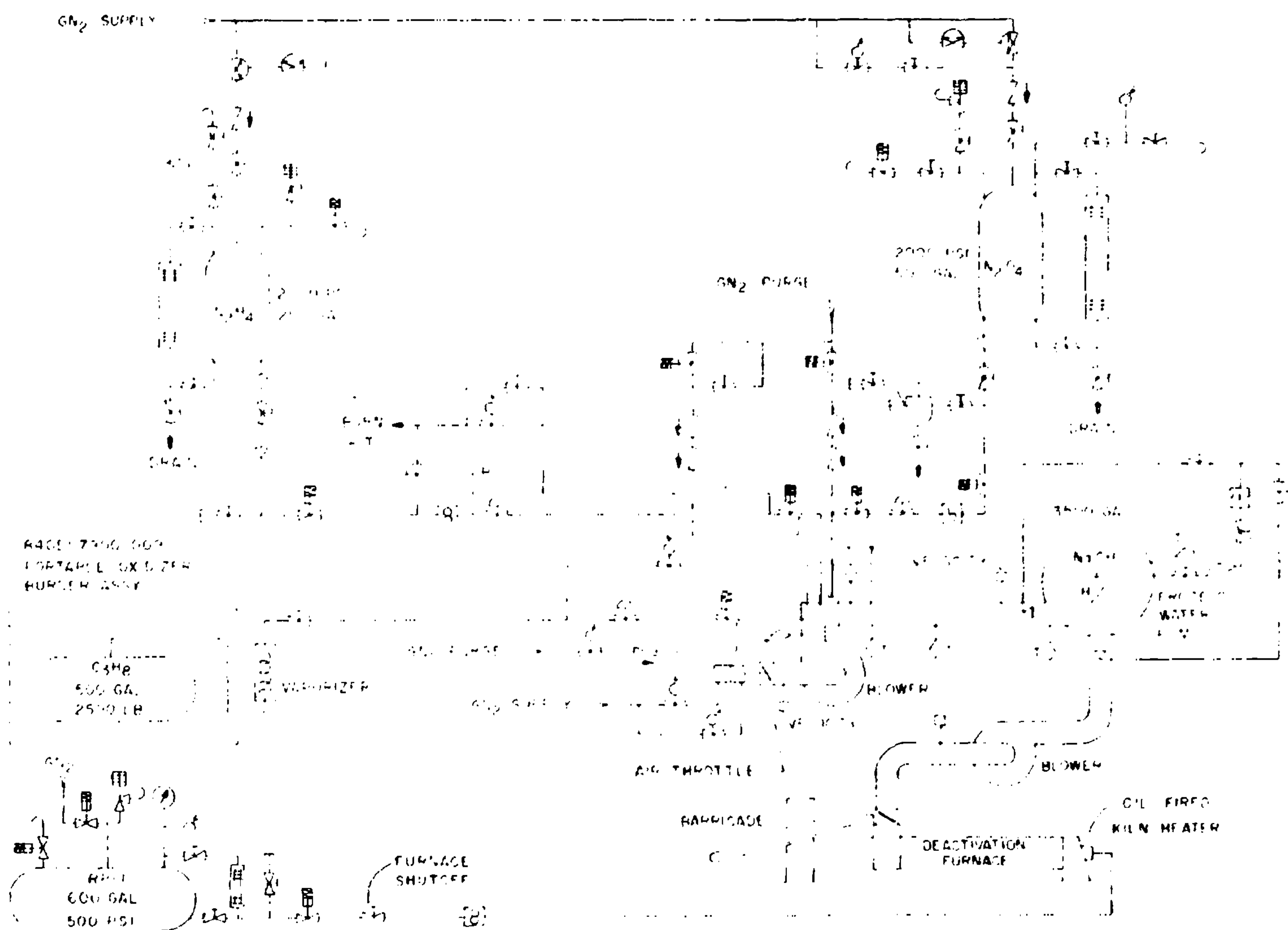


Figure 4. Waste Burner Development Facility Schematic

Rule 402 Exceptions The provisions of Rule 401 do not apply to:

a. Smoke from fires set by or permitted by any public officer, if such fire is set or permission given in the performance of the official duty of such officer and such fire in the opinion of such officer is necessary:

   1. For the purpose of the prevention of a fire hazard which cannot be abated by any other means, or
   2. For the instruction of public employees in the methods of fighting fire.

b. Smoke from fires set pursuant to permit on property used for industrial purposes for the purpose of instruction of employees in methods of fighting fire.
c. Agricultural operations in the growing of crops or raising of fowl or animals.
d. The use of an orchard or citrus grove heater which does not produce unconsumed solid carbonaceous matter at a rate in excess of one (1) gram per minute.
e. The use of other equipment in agricultural operations in the growing of crops, or the raising of fowl or animals.

Rule 403 Wet Plumes Where the presence of uncombined water is the only reason for the failure of an emission to meet the limitation of Rule 401, that rule shall not apply. The burden of proof which establishes the application of this rule shall be upon the person seeking to come within its provisions.

Rule 404.1 Particulate Matter Concentration-Desert Basin
A person shall not discharge into the atmosphere from any single source operation . . . particulate matter in excess of 0.1 grains/ft^3 of gas at standard conditions.

Rule 405 Particulate Matter Emission Rate
A person shall not discharge into the atmosphere from any source operation, particulate matter in excess of the following process weight tables. See Table I, Process Weight Table-Desert Basin.

TABLE I

Process Weight Table - Desert Basin

ALLOWABLE WEIGHT OF EMISSION BASED ON
PROCESS WEIGHT RATE

Process Wt. Lbs/Hr	Emission Rate Lbs/Hr	Process Wt. Lbs/Hr	Emission Rate Lbs/Hr
250 or less	1.03	6500	7.71
300	1.20	7000	8.05
350	1.35	7500	8.39
400	1.50	8000	8.71
450	1.63	8500	9.03
500	1.77	9000	9.36
600	2.01	9500	9.67
700	2.24	10000	10.00
800	2.43	12000	11.28
900	2.62	14000	12.50
1000	2.80	16000	13.74
1200	3.12	18000	14.97
1400	3.40	20000	16.19
1600	3.66	30000	22.22
1800	3.91	40000	28.30
2000	4.14	50000	34.30
2500	4.64	60000 or more	40.00
3000	5.10		
3500	5.52		
4000	5.93		
4500	6.30		
5000	6.67		
5500	7.03		
6000	7.37		

Where the process weight per hour falls between figures listed in the table, the exact weight of permitted discharge shall be determined by linear interpolation.

Rule 407 Sulfur Compounds A person shall not discharge into the atmosphere sulfur compounds, which would exist as a liquid or gas at standard conditions, exceeding in concentration at the point of discharge: 0. 2 per cent by volume calculated as sulfur dioxide (SO_2).

Rule 407. 1 Disposal of Solid and Liquid Wastes

a. A person shall not discharge into the atmosphere from any incinerator or other equipment used to dispose of combustible refuse by burning, except as provided in paragraphs (b), (c), or (d) of this rule, particulate matter in excess of 0. 10 grain per cubic foot of gas calculated to 12 percent of carbon dioxide (CO_2) at standard conditions.

b. A person shall not discharge into the atmosphere from any incinerator or other equipment used to dispose of combustible refuse by burning, having burning rates of 100 pounds per hour or less, except as provided in paragraph (d) of this rule, particulate matter in excess of 0. 30 grain per cubic foot of gas calculated to 12 percent of carbon dioxide (CO_2) at standard conditions and shall not discharge particles which are individually large enough to be visible while suspended in the atmosphere.

c. A person shall not discharge into the atmosphere from any equipment whatsoever, used to process combustible refuse, except as provided in paragraph (d) of this rule, particulate matter in excess of 0. 30 grain per cubic foot of gas calculated to 12 percent of carbon dioxide (CO_2) at standard conditions.

d. A person shall not discharge into the atmosphere from any incinerator or other equipment used to dispose of combustible refuse, except as provided in paragraphs (a), (b), or (c) of this rule, particulate matter in excess of 0. 10 pounds per 100 pounds of combustible refuse charged.

Any carbon dioxide (CO_2) produced by combustion of any liquid or gaseous fuels shall be excluded from the calculation to 12 percent of carbon dioxide (CO_2).

The provisions of this rule shall not apply to incinerators, approved by the governing fire control agency, used to dispose of residential rubbish by open burning as permitted by Rule 417.

The theoretical effluent gases produced by burning liquid rocket propellants such as nitrogen tetroxide, hydrazine and unsymmetrical-dimenthyl hydrazine

are not regulated by Kern County. See Table II for a listing of these theoretically predicted combustion products. The emissions of concern are therefore the solid particles in the exhaust gases. These are regulated and will be generated from burning liquid materials such as pentaborane. The effluent produced from operating the solid burner also will include solid particulate materials; the emissions of these are regulated. Solid materials will be removed by the venturi separator and the scrubber systems of the Toxic Waste Disposal Facility. Sub-micron sizes of particles are difficult to separate, may create an opaque exhaust stream and will become the emission of greatest concern. The burn rate of TWDF will create approximately 300 lb/hr of aluminum oxides or approximately 500 lb/hr of borates. The cyclone separators of the TWDF must remove enough of these solid particles to meet the requirements of Table I, which limits these emissions to approximately 2 lb/hr of aluminum oxide or 2 lb/hr of borates. These requirements exceed the limits of the range of the design specification of the TWDF scrubbing equipment. This specification requires the scrubber system to remove 98.23 percent of the solid particles in a 100 lb/hr flow that contains 18-20 percent of sub-micron particles. The true flowrate of solid particles will be 200-500 lb/hr and unfortunately most of the particulates measured during disposal of Minuteman propellants were of sub-micron sizes. More than 100 lb/hr of particles are predicted to escape the scrubber system and to increase the opaqueness of the plumes from the TWDF when the system is operated at a 500 lb/hr burn rate.

The design of TWDF provides space for installation of filters whith can be obtained commercially and installed to prevent escape of excessive particles if, in reality, that proves to be necessary.

The emission rate of particulates may also be lowered by decreasing the burn rates of solid propellants and of liquid propellants that produce solid particles.

The actual performance of the TWDF relative to the specifications or its quantitative levels is unknown at this time because construction is not complete. Research and development operation of this facility must be performed to develop operating procedures that assure compliance with the applicable emission regulations.

TABLE II

THEORETICAL COMBUSTION PRODUCTS

Reactants	Temp °F	Species	Products Weight, lb/hr	Volume ft^3/min
1. Air, 4695 lb/hr	1331°F	CO_2	353 lb/hr	
C_3H_8, 115 lb/hr		H_2O	188 lb/hr	
N_2O_4, 600 lb/hr		N_2	3841 lb/hr	
		O_2	1044 lb/hr	
		NO	5 lb/hr	
Total 5410 lb/hr				4420 ft^3/min
2. Air, 10805 lb/hr	1194°F	H_2O	639 lb/hr	
N_2H_4, 600 lb/hr		N_2	8818 lb/hr	
		O_2	1737 lb/hr	
		NO	3 lb/hr	
Total 11405 lb/hr				8605 ft^3/min
3. Air, 15600 lb/hr		H_2O	219 lb/hr	
		NO	1 lb/hr	
B_5H_9, 445 lb/hr	1270°F	N_2	12337 lb/hr	
		O_2	2996 lb/hr	
		B_2O_3	470 lb/hr	
Total 16045 lb/hr				11500 ft^3/min
4. Air, 30957 lb/hr	1701°F	CO_2	2367 lb/hr	
C_3H_8, 485 lb/hr		H_2O	1534 lb/hr	
UDMH, 600 lb/hr		NO	5 lb/hr	
		N_2	24743 lb/hr	
		O_2	3482 lb/hr	
Total 32042 lb/hr				30509 ft^3/min

Particulate emission rate will be measured during demonstration and operation of the TWDF by using two systems which will be installed in a trailer that was modified for emission measurement service. One system collects particulates which are later weighed; the second system collects particulates on a moving tape and the deposit is analyzed and its level indicated by automated atomic-electronic techniques. Emission levels will be kept within the specified limits by modification of scrubber equipment, operation of the solid burner at approximately half the design levels, or use of other suitable techniques.

PRELIMINARY DESIGN

Burning as the solution for disposal of toxic propellant wastes in the AFRPL's Toxic Waste Disposal Facility was selected by the engineering design contractor and the AFRPL project engineer. This method theoretically provides process gases which: (1) require no treatment because they are nontoxic, or (2) may be scrubbed, or (3) contain acceptable low levels or pollutants. Solid particles including borates, aluminum oxides, and chlorides are produced from some reactions. Processes considered during preliminary design efforts include the reaction of nitrogen tetroxide with propane to produce carbon dioxide and water, the burning of hydrazine in air to produce water and nitrogen, the reaction of chlorine-fluorine propellant compounds with propane to produce fluorides and chlorides which are then reacted with sodium hydroxide in the Toxic Waste Disposal Facility to produce sodium salts. The burning of pentaborane in air will produce borates which will be centrifuged from the exhaust in the cyclone separator and collected in settling basins. The burning of solid propellants will produce aluminum oxide solids and gaseous chlorides which will be removed by the Toxic Waste Disposal Facility if they are within the range of sizes and proportions described in the design specifications for the TWDF scrubber system.

BURNERS FOR LIQUID PROPELLANTS

Design Goals for Liquid Burners:

The burners for liquid propellants are targeted to operate within these design limits:

a. Flowrate: 600 lb/hr of waste propellant. Cooling air, combustion air and propane add to this to obtain total flow.

b. Exhaust Temperature: 1500°F maximum at the interface with the Toxic Waste Disposal Facility. This may be achieved by use of water injection, excess air or combustion mixture adjustment.

c. Exhaust Volume: 13000 ft^3/min (maximum) at the interface with the Toxic Waste Disposal Facility. This may be achieved by cooling the exhaust.

d. Emission Levels of Pollutants: Not to exceed the restrictions of Kern County, California. These are restrictive of only those few liquids that produce particulates when burned.

e. Burn Duration: 2 continuous hours/day.

f. Propellants which may be burned in the TWDF include, but are not limited to these:

Hydrazine	N_2H_4
Unsymmetrical-dimethyl hydrazine	UDMH
Mixed hydrazine fuels	MHF
Pentaborane	B_5H_9
Nitrogen Tetroxide	N_2O_4
Inhibited Red Fuming Nitric Acid	IRFNA

The TWDF will be demonstrated for acceptance from the contractor by the Army Corps of Engineers by burning N_2H_4 and N_2O_4 in separate two-hour burns. The full scale burners were therefore demonstrated with these propellants. Full scale operational burns of B_5H_9, MHF, or others will be performed in the operation of the TWDF if the requirement arises at some future time.

The contractual agreement for construction of the Toxic Waste Disposal Facility stipulated that AFRPL would supply the required burners. Development was assigned to the Test and Support Division who considered several sources of burners and attempted to contract for suitable commercial units.

The burner for liquid propellants was characterized during preliminary design studies to have these features:

a. It will be built of readily available materials.

b. It will utilize inexpensive, commonly available fastening and forming processes.

c. Temperatures will be kept as low as possible to minimize problems of the fabricated material and to reduce the formation of nitrogen oxides. Unfortunately this feature clashes with the necessity to maintain temperatures high enough to decompose materials such as diethylamine and unsymmetrical-dimethyl hydrazine.

d. Air will be used at low pressure as a coolant and/or oxidizer because:

   1. It is readily supplied through commercially available blowers.
   2. It is inexpensive to supply.
   3. Low pressure ducting which is inexpensive and easily fabricated may be used.
   4. Control of air flow rate is readily achieved with commercially available flow controller systems.
   5. There is no storage system required.
   6. The theoretical chemistry predicts nontoxic exhaust products from burning the wastes such as nitrogen tetroxide and hydrazine which are most likely to occur in large quantities and indicates treatable or scrubbable products from many other materials.

The preliminary burner design based on these considerations included the following components:

a. A cylindrical housing made of carbon steel.

b. An industrial blower feeding air to the combustion process and blowing in excess air for cooling.

c. Valves to control both flowrates and sequences of propellants waste, propane, and air.

d. A cylindrical combustor of corrosion resistant material placed concentrically inside the burner housing.

e. The necessary flowmeters, thermocouples, and pressure transducers to measure parameters required to determine ratios of propellant/propane/air and to control-monitor temperature of the combustor, housing, and the exhaust gases.

Sub-Scale Burners:

Burners capable of less than full-scale 600 lb/hr disposal rates were built and operated in the sub-scale phase of this program in 1972-1973-1974. These operations provided:

a. Evaluation of burner designs.
b. Personnel trained to operate waste burners.
c. Knowledge of exhaust products derived from sampling and analysis data.
d. Operating personnel for pollution sampler-analyzer equipment including chemiluminescent and infra-red systems.
e. Design data for the TWDF including proven operating ratios for propane/air/toxic waste.
f. Design data for full-scale burner design.

Titan N_2O_4 Vent Gas Burner:

Vented N_2O_4 vapors were burned with propane (C_3H_8) in TITAN Aerospace Ground Equipment (AGE) to change this toxic material to non-toxic gases. One of these burners was modified by mounting it in a cylindrical housing and forcing air into the process stream with a vane-type ventilation system fan. The burn rate was less than 1/2 of full-scale due to limited propane, propellant, and air supplies.

This burner assembly utilized surplus materials which were available at AFRPL. Valuable operating experience was derived from use of this burner, people were trained in use of pollution sampler analyzers, and design data for larger burners were obtained.

These design data were derived:

a. Blowers that produce higher than 1" H_2O static pressure are necessary to overcome pressure pulsation in the enclosed burner housing and ducting.
b. Remotely controlled air inlet flowrate is needed to adjust for system pressure changes as flowrates of C_3H_8, and waste propellant are varied during experiments.

TABLE III

SUBSCALE BURNING OF LIQUID PROPELLANT

TOXIC WASTE	BURN RATE, LB/HOUR		AIR FLOW	WATER	EXHAUST GAS		NITROGEN OXIDES
	WASTE	PROPANE	LB/HR	INJECTED, LB/HR	TEMP °F	VOLUME, FT^3/MIN	PARTS/MILLION
N_2O_4	348	85	5248	NONE	960	3965	592
N_2O_4	440	86	5248	NONE	735	3389	750
N_2O_4	381	74	5248	NONE	789	3498	673
N_2O_4	500	104	5248	966	762	4090	762
N_2O_4	588	103	5248	813	1247	5660	613
N_2O_4	NONE	72	5248	179	959	3833	87
N_2O_4	122	80	5248	191	1123	4385	253
N_2O_4	200	91	5248	237	935	3956	248
N_2O_4	282	91	5248	NONE	921	3815	779
N_2O_4	344	91	5248	NONE	887	3759	1016
N_2O_4	426	91	5248	NONE	948	4032	2316
N_2O_4	322	179	11335	1872	989	9759	727
N_2O_4	245	179	11335	1872	1019	9900	705
N_2O_4	172	180	11335	1872	876	8896	590
N_2H_4	180	128	8015	368	350	3458	216
N_2H_4	210	128	8015	NONE	2150	10710	288
N_2H_4	290	130	8015	1912	434	4545	185
N_2H_4	77	132	8015	1909	463	4594	98
MMH	434	1	9817	1911	1530	11887	451
MMH	371	1	9817	1910	1388	10983	438
MMH	310	1	9817	1910	968	8443	357
MMH	244	1	9817	1913	785	7322	295
MHF5	308.	144.	8015.	NONE.	1554.	8378	151
50-50	114	138	11335	NONE	1846	13128	846
50-50	114	71	11335	NONE	1572	11500	758

TABLE III (Continued)

TOXIC WASTE	BURN RATE, LB/HOUR		AIR FLOW	WATER	EXHAUST GAS		NITROGEN OXIDES
	WASTE	PROPANE	LB/HR	INJECTED, LB/HR	TEMP °F	VOLUME, FT^3/MIN	PARTS/MILLION
DETA	290	43	8015	NONE	2194	10885	1402
DETA	283	43	8015	NONE	2192	10865	1382
DETA	284	64	8015	NONE	1678	8784	379
DETA	237	137	5668	1250	1854	8287	1149
BA1014	237	46	8015	NONE	1223	6859	394
BA1014	235	40	8015	NONE	1794	9179	954
BA1014	296	40	8015	NONE	1975	9990	1096
BA1014	62	273	8015	NONE	369	3401	158
BA1014	75	40	8015	NONE	1057	6057	216
BA1014	128	40	8015	NONE	1306	7099	544
UDMH	494	137	5668	1247	1902	8754	728
UDMH	493	3	5668	1247	1916	8649	468
UDMH	373	3	5668	1243	1933	8564	1756
UDMH	196	3	5668	1240	1844	8184	854

c. N_2O_4 and IRFNA combust more readily if preheated to raise their vapor pressure at the injection point. This qualitative assessment is based on color of the exhaust gases and on analysis of their NO_x levels.

d. Levels of NO_x below 1000 ppm are produced from combustion of N_2O_4 - C_3H_8 in excess air if the N_2O_4 is heated to raise vapor pressure. 150°F will produce adequately high vapor pressure in the N_2O_4 and was readily attained by exposing the burner inlet propellant lines to heat from the burner exhaust duct.

Mechanically Scaled-Up Burners:

Larger burners were next designed and built based on information obtained from the modified TITAN N_2O_4 burners. These components were made full-scale:

a. The burner housing
b. The burner flange
c. The air inlet
d. The combustor

This burner, however, was not full-scale, because blowers of adequate pressure and power were not on han Blowers were ordered as long lead time items, and a substitute vane type blower typically used in air conditioning systems was temporarily used to force air into the burner system. This blower provided 1" H_2O static pressure which was inadequate; and it lacked sufficient air volume for full-scale fuel disposal. An ignition system was developed, combustor designs were evaluated, and additional valuable experience was gained in operating burners, analyzers, and process control systems.

These efforts provided the full-scale burner for the TWDF, except for the final blower and the mounting framework. Modifications to the combustors were made, including use of perforated sheets of nickel-alloy-steel which was rolled so as to form combustor walls.

Data relating flowrates, temperatures, and exhaust volume were derived from these tests. The exhaust volume is not measured; it is calculated from the total inlet flow, exhaust temperature, and pressure. Nitrogen oxide content of

the exhaust was analysed by infra-red sensing and by chemiluminescence detection equipment.

Although Ke. County does not restrict emissions of nitrogen oxide at this time from stationary combustors of the toxic waste burner class, this material is of interest because of possible effects on personnel who work in the TWDF area. If concentrations of NO_x exceed existing basin air quality levels, regulation of NO_x may occur. The nitrogen oxides may also be of concern to planners who wish to install similar equipment in other locations and should be minimized where possible within the state-of-the-art of pollution abatement.

A van type vehicle containing sampler-analyzer equipment will be used during operation of the TWDF. Instruments and batch samplers will be provided to obtain data on nitrogen oxide levels, particulate levels, carbon monoxide levels, and hydrocarbon levels.

Full-Scale Burners:

Full-scale burners for liquid propellants were completed in 1974 when blowers of adequate pressure and flowrate were received. These units used the housing, ignition system, and combustor developed during 1973 in sub-scale burner operations.

This final design was completed by providing a mounting base for the motor and the blower, and the necessary flanges to attach both the already proven burner housing and the combustor to the large blower. Flow controllers, shut-off valving, and instrumentation systems used in smaller scale tests were also used in the full-scale burns.

Demonstration burns of N_2O_4, IRFNA, and N_2H_4 were completed in 1975 using full-scale burners to qualify the liquid burners for use in the Toxic Waste Disposal Facility. Burners of the same design proven in these demonstrations will be installed in the TWDF. These operations were completed to demonstrate that durability of the burners is adequate for repeated burner operations of 2 hours duration at 600 lb/hr flowrates of N_2O_4 and of N_2H_4. See Table IV for operating data and Figures 5, 6, and 7 for configuration on the full scale burners.

TABLE IV

FULL SCALE BURNING OF LIQUID PROPELLANTS

	FLOW RATES, LB/HOUR				EXHAUST GAS	
TOXIC WASTE	WASTE	PROPANE	AIRFLOW	WATER INJECTED	TEMP °F	VOLUME, FT^3/MIN
IRFNA	912	58	8712	1915	427	5050
IRFNA	860	74	8290	1793	126	3172
IRFNA	1190	80	9371	2069	107	3537
N_2O_4	680	52	23706	NONE	1290	20692
N_2O_4	650	29	19231	534	678	10962
N_2O_4	630	56	5445	2534	1486	8158
UDMH	690	57	21434	NONE	1252	18372
UDMH	713	28	20054	NONE	811	12777
UDMH	707	1	21859	NONE	157	6729
UDMH	697	32	21764	NONE	920	15003
N_2H_4	1066	NONE	13754	2631	151	5153
N_2H_4	1043	NONE	12054	NONE	1328	11318

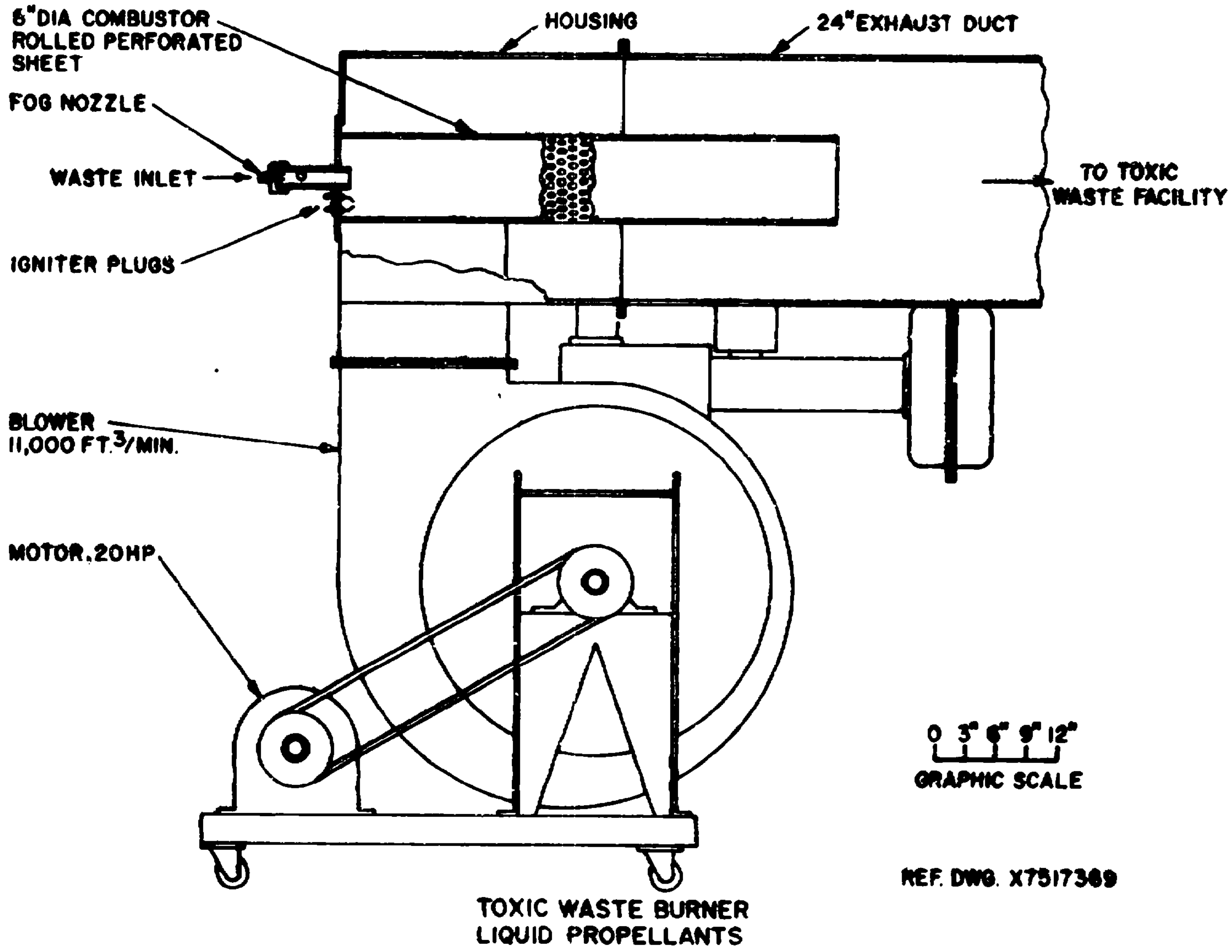


Figure 5. Toxic Waste Burner Liquid Propellants

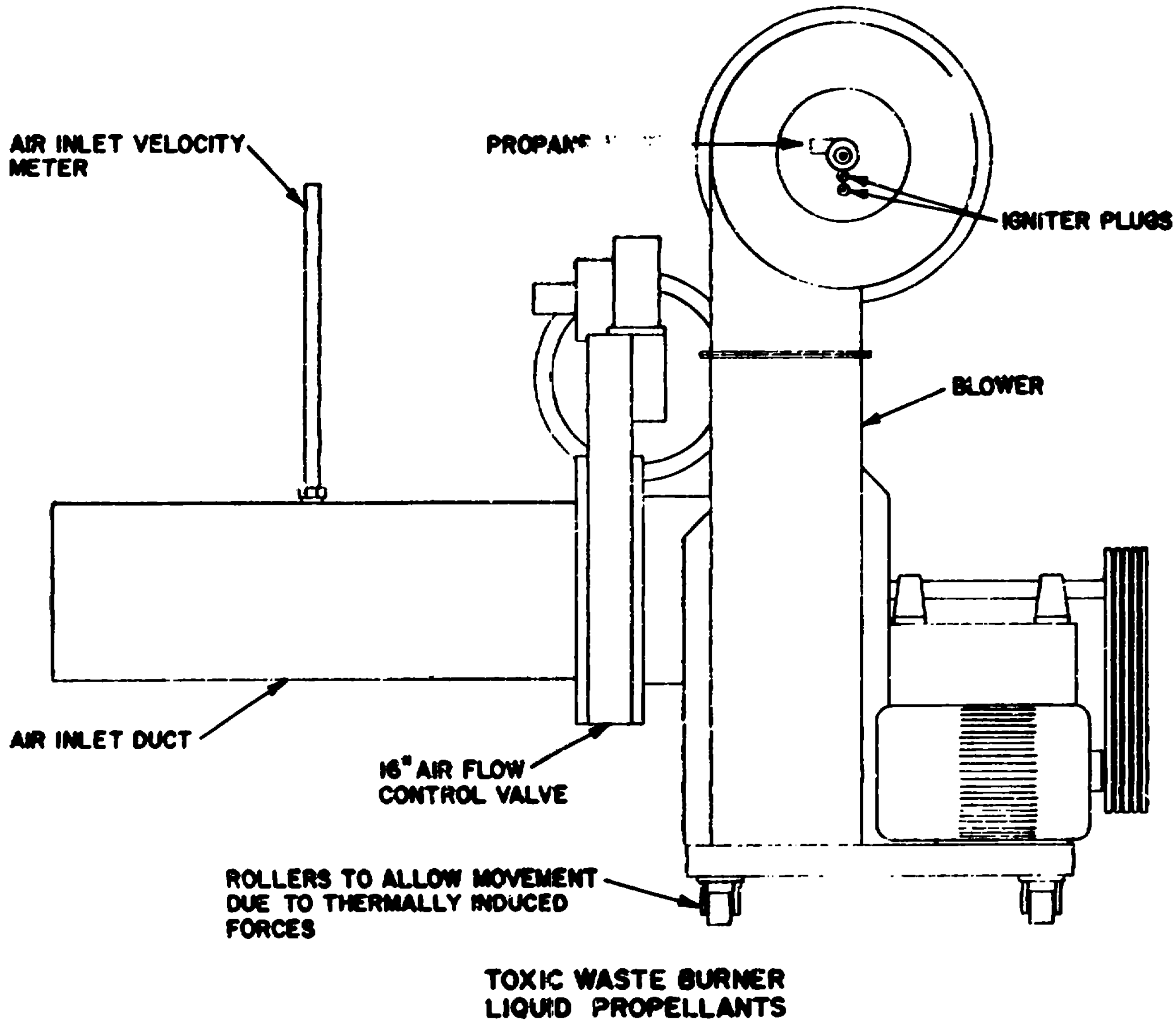


Figure 6. Toxic Waste Burner Liquid Propellants

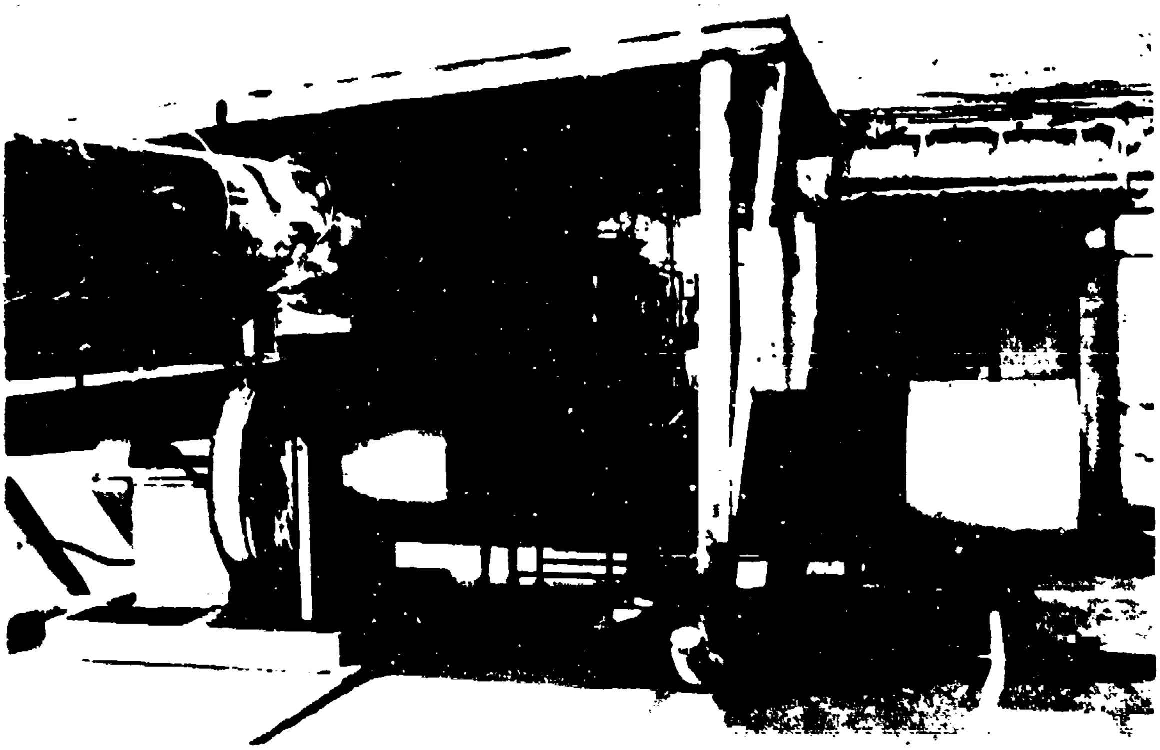


Figure 7. The Full Scale Burner for Liquid Propellants Disposal

Pollutant levels produced by these full-scale burner operations were not monitored by the electro-mechanical analyzers as they were during burns at smaller flowrates. The data from those smaller scale operations, however, are predicted to be similar to data that would occur from large scale burner operations and may be extrapolated to the large scale tests to provide guidance in estimating the levels of nitrogen oxide produced by full-scale burners. The same parts-per-million levels are predicted to occur in operation of the full-scale burners that occurred during operation of smaller burners. The flowrate of oxides in the exhaust gases will be proportional to total flowrates at identical conditions of temperature and propellant/air/propane ratios. The combustor portions of full-scale and reduced scale burners are very similar and will produce similar combustion products.

Two full-scale burners including valving, ducting, blowers, and instruments were assembled onto supporting structures shown in Figure 8 and delivered in December 1975 to the contractor for TWDF. These will be the units used in demonstration operations of this new AFRPL facility during 1976.

Operating the Liquid Burner:

This operation consists basically of: (1) starting a C_3H_8 - air flame in the combustor, (2) adding C_3H_8 to react with oxidizers or to heat the less easily vaporized fuels such as diethyltriamine (DETA), (3) spraying waste into the burner for disposal. To perform this operation, these basic steps are completed in the listed order:

a. Pressurize the loaded waste tank to 80-150 psig.
b. Set the flow controllers at suitable values specified in the Engineering Request covering the disposal action.
c. Command "IGNITION"
   1. The C_3H_8 igniter valve opens.
   2. The igniter arc is energized.
   3. The automatic logic circuitry will detect ignition by sensing the heat rise in the combustor.
   4. If ignition is detected before 3 seconds has elapsed the C_3H_8 burner valve opens. (If not, shutdown occurs).

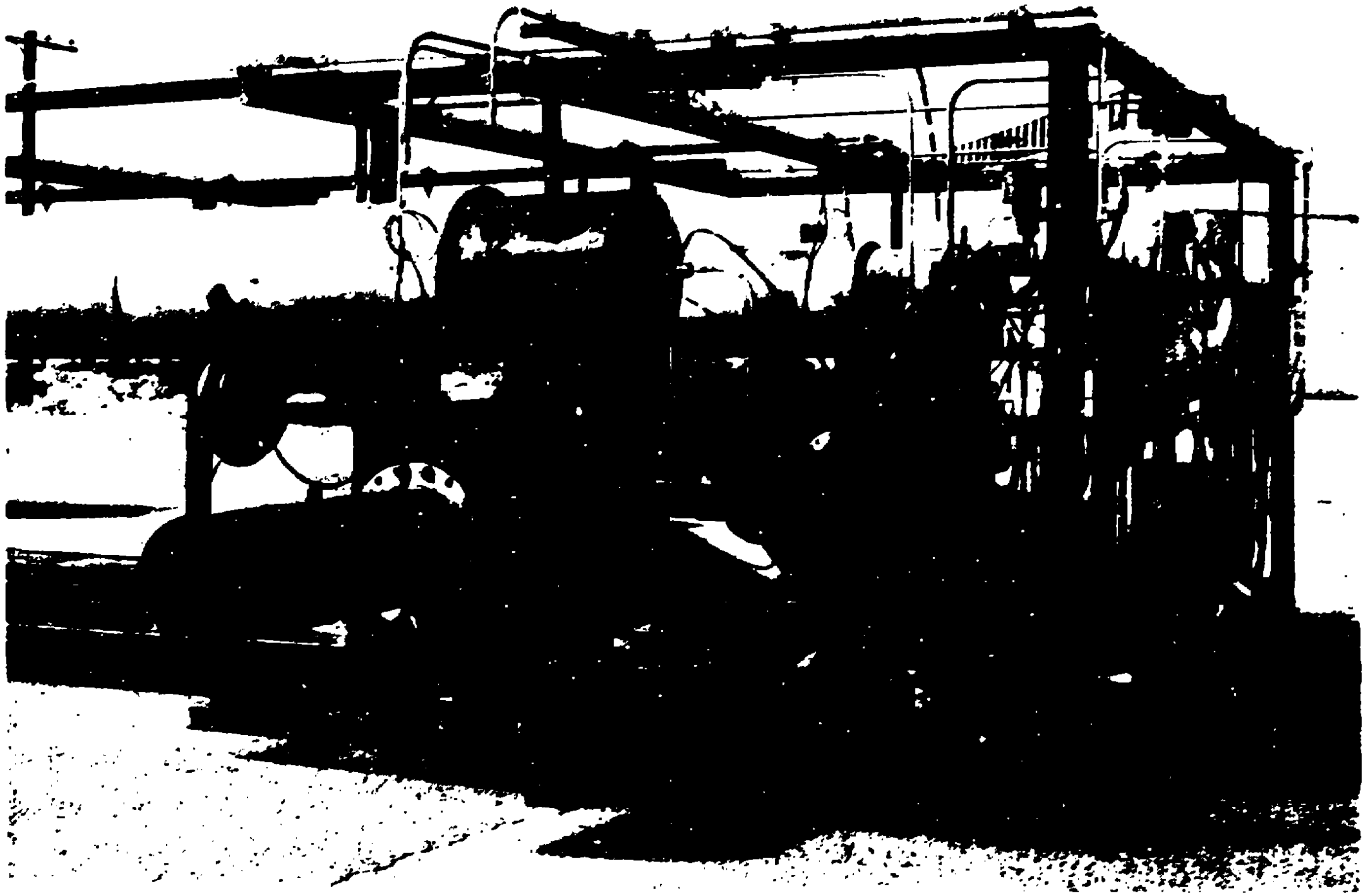


Figure 8. Liquid Burner Assembly for the Toxic Waste Disposal Facility

5. If step C.4. is completed, the waste valve opens and the ignitor valve and ignition arc shuts off.

d. Monitor temperatures throughout. Do not exceed 2000°F at any point.

e. Complete the disposal. Command "STOP."

1. The waste valve closes.
2. The waste line is purged for 15 seconds.
3. The C_3H_8 valve closes.
4. The C_3H_8 line downstream of the shutoff valve is purged for 15 seconds.

f. Turn blower OFF.

These sequences may be provided by electro-mechanical timers, a computer, or other source in the facility including manual operator actions.

Manual control and electro-mechanical sequencers were both used. A digital format computer will be used in the TWDF to supply these command sequences; to control the scrubber facility, to maintain proper limits of flow, temperature, and pressure; to record data, and to compute data.

BURNERS FOR SOLID PROPELLANTS

Design Goals for the Solid Burner:

The burner for solid propellants is restricted to a lower burn rate than the burner for liquid propellants because of both the greater probable quantities of solids produced and the higher concentration of toxic gases. These must be chemically reacted and removed from the exhaust by the Toxic Waste Disposal Facility. The other limitations are the same. They are:

a. Flowrate: 500 lb/hr of propellant.

b. Exhaust temperature at the interface with the TWDF: 1500°F, maximum.

c. Exhaust flowrate at the interface with the TWDF: 13000 Ft^3/min.

d. Emission levels of pollutants: Not to exceed the restrictions of Kern County, California.

e. Burn duration: 2 hrs/day, nominal.

Propellants which may be burned in the solid burner include but are not limited to:

Class 2

- Minuteman grain portions
- Tensile test specimens
- Chips, cuttings, sawdust

Class 7

- Minuteman grain portions
- Tensile test specimens
- Propellant aging samples

The solid propellant materials that are residuals from propulsion research programs conducted by the Air Force Rocket Propulsion Laboratory vary greatly in size, shape, and packaging materials. These waste materials include full scale rocket motors, chips from sawed tensile test specimens, small sheets of materials from aging tests, overpours which are typically held in cylindrical one-half gallon size ice cream packages and test tubes containing chemicals.

Reduction of these materials to uniformly small sizes which might be readily pumped or blown into reaction processes was judged to be impractical because of included casing parts and the extremely varied sizes to be disposed of.

The solid materials range from highly reactive propellants and chemicals to relatively inactive billet materials such as boron-filled fuels, liners, and case materials. This variability in reactivity makes a single optimum reaction condition difficult to select. These design considerations demand a burner system that can accept a wide range of sizes and shapes of materials which vary greatly in reactivity.

Evaluation of the Solid Burner:

The Tooele Army Depot (TAD) developed a rotary kiln type of ammunition deactivation furnace in which ammunition is disposed of by heating it above its ignition temperature. This rugged device is capable of disposing of explosive

ordnance of a range of physical shapes, sizes and energy content which makes it suitable for use by AFRPL in disposing of cartons, packages, and blocks of solid rocket propellant that are typical residue from propulsion research.

Use of this unit potentially provided many advantages and an agreement between AFRPL-TAD was reached whereby a deactivation furnace would be evaluated. The advantages include:

a. It is a reliable unit that has been proven over many years in Army, Navy, and Air Force use.
b. It is an extremely rugged device that routinely contains blasts from grenades and high velocity ammunition.
c. Development and design costs are amortized.
d. It is adaptable to use by AFRPL.
e. Replacement parts are available from commercial sources and these sources are well established thus improving the probability that parts will be available for many years.
f. TAD people were very cooperative in providing technical knowledge, practical operating procedures, and in solving procurement problems.

In April 1973 TAD-AFRPL cooperatively evaluated this burner at Tooele, Utah by feeding it Minuteman Class 2 and Class 7 propellants at the design feed range of the TWDF. This burner proved to be a suitable component for the TWDF and one was purchased from the Army. It was installed during 1974 at AFRPL in the 1-46 Test Area and a wide range of sizes and shapes of solid propellant wastes were burned in it. It will be installed in the TWDF and used to detoxify the toxic solid materials generated during propulsion research at AFRPL.

These data were obtained during evaluation, and use of the propellant burner was designed by TAD:

a. An exhaust blower must be coupled to the exhaust to prevent escape of gases to the operating area from the kiln which fits loosely into the exhaust stack; ambient air flowing into the retort opposes outflow of propellant gases from the retort.

b. The burner will burn 500 lb/hr to 900 lb/hr of Minuteman propellant which exceeds the requirement of the TWDF.

c. The furnace inlet must be cooled to prevent premature ignition of bare propellant in the inlet chute. A fine spray of water proved to be satisfactory.

d. Propellant must be no larger than 6" in maximum dimension to prevent jamming in the inlet. A cube, cylinder, or spheroid approximately 4" in height and width is suitable. These shapes may be propellant cuttings in bags, boxes, or other containers, or pieces of bare propellant; even test tubes or bottles of solid, slurry or liquid materials may be converted to gases.

e. Some way of clearing the inlet chute by a remotely controlled action when propellant lodges in it is desirable. A water jet blast or pneumatically driven ram that is remotely actuated will be installed. This feature is required to eliminate the hazard of explosion or burns to personnel who otherwise might be exposed.

f. The Tooele Army Depot deactivation furnace proved to be highly reliable and rugged, and provided the desired variability of feed conveyor speed and kiln rotation velocity necessary to obtain burning near the mid point of the rotating kiln in its strongest section.

g. Surplus liquid propellants may be used in this burner to heat the kiln, thus providing an added disposal action. Rocket Propellant 1 (RP1), a hydrocarbon, was used at AFRPL.

h. Metallized Class 2 propellants produced opaque exhaust streams because more than 80% of the aluminum oxide particles created by their burning were less than 1 micron in largest dimension. Small particles will create a significant problem of removal in situations where opaque exhaust streams are not acceptable because of legal restrictions on opacity and/or on certain species due to their toxicity.

TABLE V

RESULTS OF SOLID BURNER OPERATION

Propellant	Form	NO_x	Feed Rate
Class 2 Minuteman	Hand formed rubbery sludge washed from motors	160 ppm	400-600 lb/hr
Class 7 Minuteman	Sawed tensile test specimens, blocks, slabs, casing with propellant	1200 ppm	565 lb/hr

Operation of the Burner for Solids:

The operation of the burner to dispose of solids is basically the practice of heating the material to be disposed of until it ignites and turns to gases or turns to molten or solid waste materials which are accumulated in suitable containers. The gases produced from burning solid propellants may include hydrogen chloride which is treatable by NaOH to provide nontoxic salts. Protection from blast and heat for the operators who hand feed the burner is provided by a heavy earth-filled barricade between the operator and the burner. Equipment to feed the burner by remote action is not installed but can be developed from commercially available equipment such as bins, vibrators, and conveyor equipment used by mining and food processing industries.

Detailed operating and adjustment procedures are fully explained in the excellent operator's manual supplied by TAD with each burner. These basic steps must be performed to operate the solid propellant burner: (Refer to the TAD operation and maintenance manual for troubleshooting)

a. Check the fuel supply reservoir which feeds the retort heater-burner. 10 gallons/hour of diesel, RP1, or similar fuel are necessary. Adaptors for use of propane are available and one is on hand at AFRPL.
b. Pressurize the fuel supply system to 35-50 psig.
c. Open oil supply line valves between the supply reservoir and the retort heater-burner. See Figure 4.

d. Verify that the oil pressure regulator at the burner supplies 7-10 psig.

e. Turn all control and power supply breakers to "ON" in the electrical console at the feeder end of the burner.

f. Set temperature control to 50°F at the temperature recorder on the console.

g. Set cycle switch "UP."

h. Press "BLOWER" switch on left side of console.

i. Wait 3 minutes for "READY" light, then

j. Press "START" switch.

   Wait 3 minutes to determine that burner is started.
   Automatic detectors and logic circuitry will shut the burner oil valve and sound a warning if the burner flame dies.

k. Heat the kiln by operating the burner for 10 minutes.

l. Set the high temperature set point at 1000°F at the temperature recorder-controller.

m. Press "RETORT" start button. Verify that the retort is rotating.

n. Heat the retort for approximately 1 hour to 1000°F. This is an appropriate period to bring propellant from storage and complete other preparations.

o. Start exhaust blower by pressing "BLOWER" on right hand side of console.

p. Press "CONVEYOR" start.

q. Feed propellants onto feeder at rates specified by the test conductor. An engineering request will be prepared and followed for each disposal action. Propellant characteristics, scrubber capacity, and burner limitation shall be observed.

r. Turn off all blowers, feeders, and the oil supply when the disposal is completed. Do not turn off "RETORT" until the kiln has cooled to 200°F.

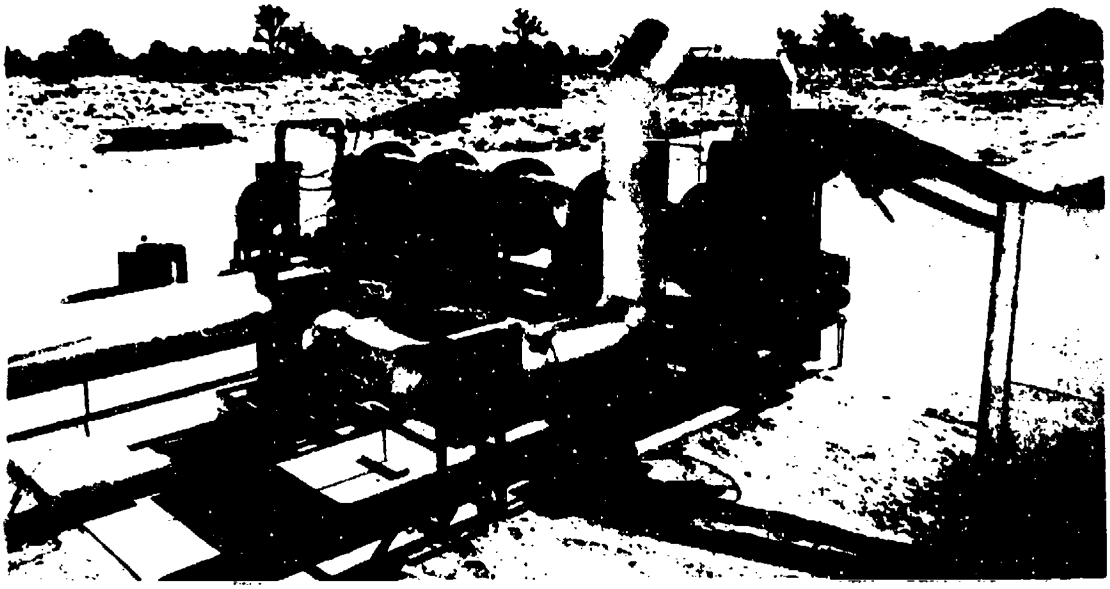


Figure 9. AFRPL Burner Installation for Solid Propellants

CONCLUSIONS

Toxic materials including nitrogen tetroxide, inhibited red fuming nitric acid, hydrazine, unsymmetrical-dimethly hydrazine, and mixed hydrazine fuels that are typical residual wastes from rocket propulsion research can be reacted with propane in the presence of air or with air alone in burning processes that theoretically convert them to nontoxic gases. Burners were developed for this purpose by the Air Force Rocket Propulsion Laboratory and will be installed in the Toxic Waste Disposal Facility. Measured levels of nitrogen oxides in the exhaust of these burners will be less than 1000 parts per million.

Solid propellant scrap may be successfully disposed of by burning it in a modified ammunition deactivation furnace. Toxic hydrogen chloride gas and opaque clouds of white aluminum oxide are emitted from this burning process. These undesirable materials will be treated by the scrubber system of the Toxic Waste Disposal Facility.

The aluminum oxide solids produced by burning aluminized propellants will be extremely difficult to remove from the exhaust stream of the toxic waste disposal facility because the major part of the population of particles is of sub-micron sizes in amounts that exceed the design specification of the Toxic Waste Disposal Facility. This facility will be operated at decreased burn rates if necessary so as to meet the requirements of Kern County. Filters may also be added to remove particles from the exhaust stack gases. The burn-scrubber combination will meet the pertinent regulations when these techniques are applied.

The Toxic Waste Disposal Facility must be operated at various conditions of propellant feed rate, air flow, scrubber liquid flow and others to fully determine its potential for removal of pollutants. These tests will also determine operating techniques and equipment modifications that may be required. This is a development-research facility.

RECOMMENDATIONS

The burners developed in this program should be operated in conjuction with the Toxic Waste Disposal Facility to develop operational procedures and equipment for use in disposal of toxic wastes produced during Rocket Propulsion research by AFRPL.

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